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THE ROYAL ASTRONOMICAL SOCIETY OF CANADA

DEVOTED TO THE ADVANCEMENT OF ASTRONOMY AND ALLIED SCIENCES

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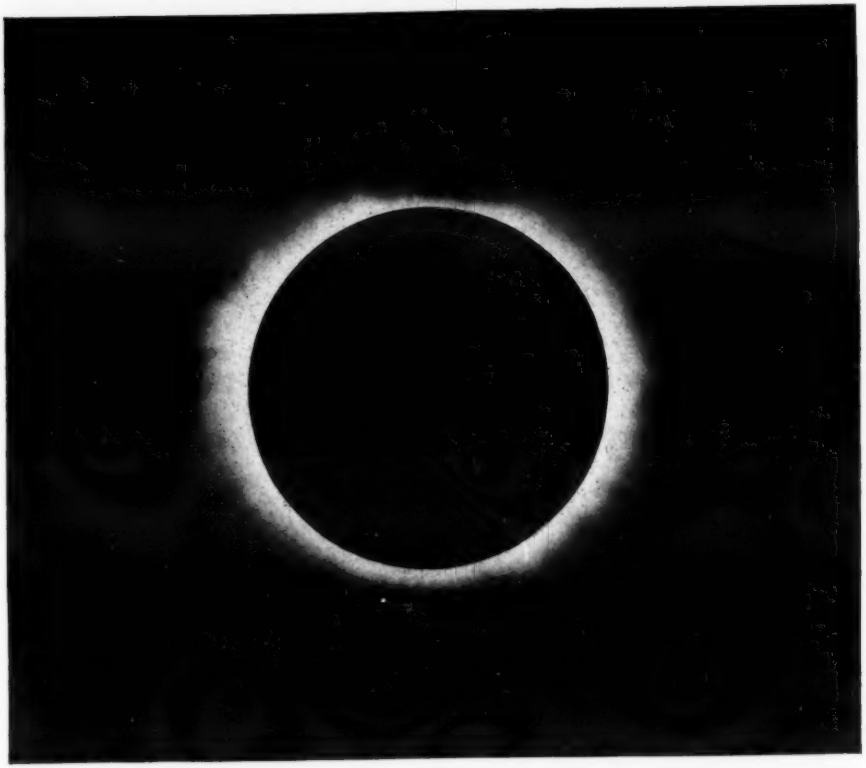


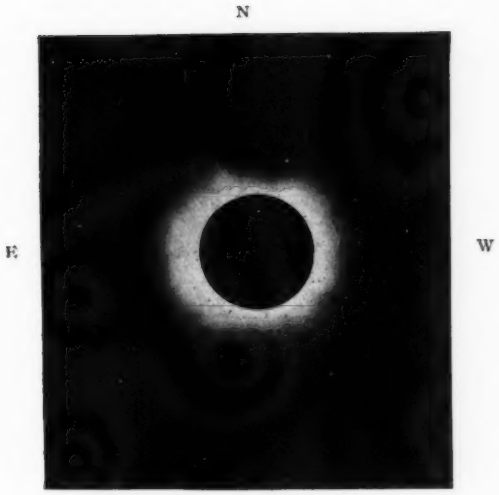
W

THE SUN'S CORONA, ECLIPSE OF JANUARY 3, 1908.

Taken with 40-foot Camera, Exposure 16 secs. Lick Observatory Expedition to Flint Island.

A large Prominence in the S. W. Quadrant.

PLATE III.



THE GENERAL FORM OF THE OUTER CORONA, ECLIPSE OF JANUARY 3, 1908.

Taken with the Floyd Camera : Aperture 5 inches, $f = 67$ inches.
Exposure 16 seconds.

Much detail on the original negatives cannot be reproduced on paper.

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THE LICK OBSERVATORY-CROCKER EXPEDITION TO FLINT ISLAND

BY SEBASTIAN ALBRECHT

THERE is no subject of greater importance to the progress of astronomy than the study of the Sun. The Sun is one of the ordinary stars, and the only one close enough to allow of being studied in more or less detail. Even in our greatest telescopes magnifying 3000-fold, stars are mere point-images, which must be studied as a whole. Without a detailed knowledge of the Sun we cannot hope to draw correct inferences in regard to the complex phenomena of the stars.

It is hardly necessary for me to point out the importance of observing the Sun at times of total eclipse. I need only mention the fact that the reversing layer, the chromosphere, the prominences and the corona were discovered at eclipses, and that some of these features of the Sun are still best observed at eclipses. The corona, the most fascinating solar feature, is exclusively an eclipse phenomenon. The observed interrelations between various solar phenomena—as for example, the close relation between the general form of the corona and the sun-spot curve—

have shown that periodicity plays an important part. It is, therefore, essential that observations should be obtained at every available opportunity. Perhaps the greatest value in such observations will lie in the continuity of the series.

For the eclipse of January 3, 1908, the Moon's shadow swept easterly across the central Pacific Ocean, and left the Earth at sunset on the western coast-line of Costa Rica. Only two islands, Hull Island and Flint Island, were in the shadow-path. The eclipse lasted sixty per cent. longer and the Sun was much nearer the zenith at Flint Island than at Hull Island. As both were equally difficult of access Director Campbell selected Flint Island as the station for the ninth L. O. Crocker Eclipse Expedition.

As Flint Island is on no steamer route, the Navy Department arranged that the U. S. gunboat *Annapolis* should meet us at Tahiti, and transport the expedition to Flint Island about four weeks before the eclipse and back again to Tahiti after the eclipse. The trip from San Francisco to Tahiti was made on the steamship *Mariposa* of the Oceanic Steamship Company. The party consisted of Director and Mrs. Campbell, Astronomers Perrine and Aitken, and the writer, from Mount Hamilton, and Prof. E. P. Lewis, of the Department of Physics, University of California. At the suggestion of Dr. Campbell, the Smithsonian Institution sent an expedition to study the heat radiations of the corona by means of a bolometer. This party, consisting of Director C. G. Abbot of the Astrophysical Observatory of the Institution and his assistant Mr. A. F. Moore, of the University of California, joined us in San Francisco. Prof. Benjamin Boss, in charge of the U. S. Naval Observatory at Pago Pago was invited to join our party on board the *Annapolis*.

We sailed from San Francisco on November 22nd, arriving at Papeete, Island of Tahiti, on December 4th. Three busy days were spent in Papeete in transferring the freight to the *Annapolis*, and in gathering up fruit and other perishables, a supply of mineral drinking water, a surf-boat for landing on Flint Island, and in picking up our Tahitian carpenter, cooks, and

laborers. On the evening of the 7th the *Annapolis* left Papeete, arriving at Flint Island at about one o'clock on the afternoon of the 9th.

Landing, on Flint Island, is possible at only one point, on the northwest side of the island, where a narrow and shallow passage has been blasted out in the horizontal shelf of the reef. The landing, which is accomplished by means of surf-boats, is dangerous except when the surf is low. The natives are experts in effecting a landing through the surf, and the process is very interesting. They hold the surf-boats just outside of the reef and watch the incoming waves until they are favorable, and then make a sudden dash into the narrow passage.

The necessity of landing through the surf caused us a good deal of anxiety before we reached Flint Island, as it might have been a serious matter to get our instruments and supplies safely on shore. When Mr. Hawk, the manager, rowed out to the *Annapolis*, he brought us the comforting information that in his twenty-seven month's residence on the island he had never seen the surf running lower. Accordingly the landing of our freight was rushed with three surf-boats and the help of the natives and some of the ship's men, and by eight o'clock in the evening the forty tons of instruments, tents, lumber, and supplies were safely landed and the *Annapolis* had started back to Tahiti. A tramway, running from the landing-slip to the company's store-houses, was utilized in transferring the freight as rapidly as it was landed and checked off.

Flint Island is situated 390 nautical miles northwest of the Island of Tahiti. It is a low island of coral formation, about 2½ miles long, in the north and south direction, and ½ mile wide. The highest point is 22 ft. and the average height about 13 feet. At the water-line, and extending entirely around the island, is a low, flat reef, only one or two feet above mean sea-level, and having an average width of about 200 feet. The outer edge of this shelf dips off very abruptly. A beach of white coral sand and gravel rises gradually from the inner edge of the shelf with an average width of about 150 feet. The entire area inside of

the beach is densely covered with trees—the southern one-fifth with native trees and the northern four-fifths with cocoanut trees, which were planted about twenty years ago. The ground is loose coral gravel and sand partly disintegrated. Two small lagoons of brackish water in the interior of the island mark the places from which formerly large amounts of guano were taken.

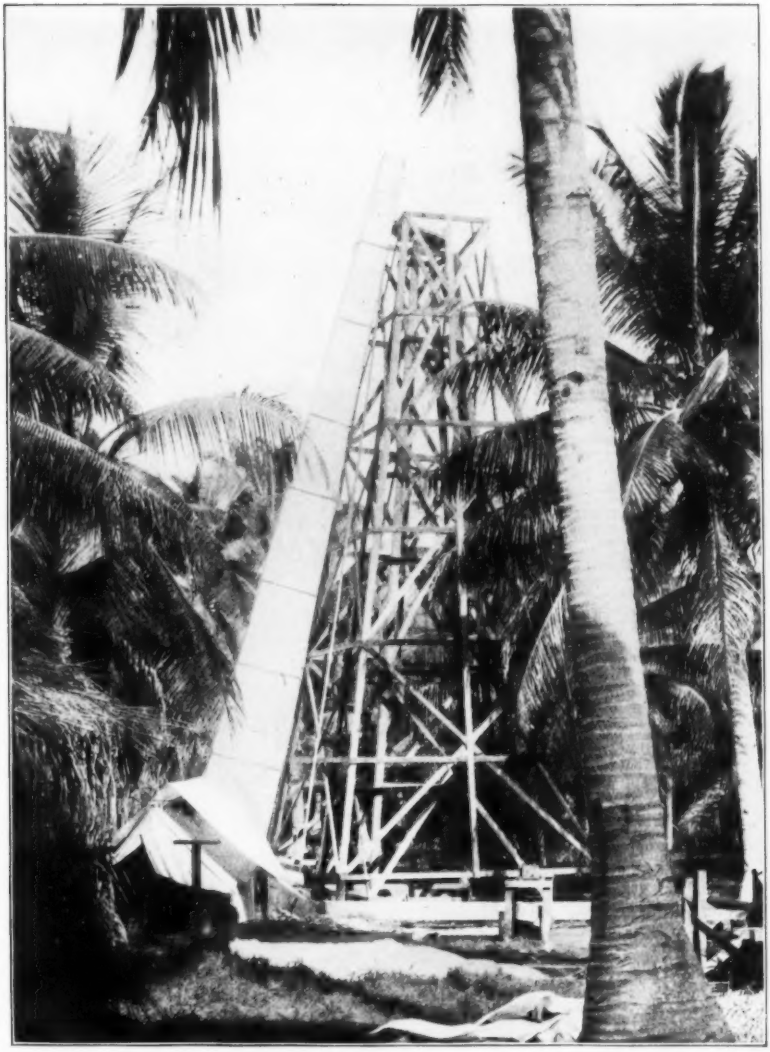
Flint Island is a British possession. It is leased by Lever's Pacific Plantations Limited. The only inhabitants are the English manager and about 25 South Sea Islanders brought there from other islands, principally Tahiti. The natives gather the cocoanuts, cut the meat out of them and dry it on racks. The dried cocoanut meat, known as *copra*, is the only product of the island. About 200 tons of it are produced annually, a small sailing schooner calling twice a year to take away the supply. There are large numbers of birds on the island, principally the black tern, the white tern and the frigate bird, and their chatter goes on continuously, day and night. The description of the island would not be complete without mention of the thousands of crabs—hermit crabs, land crabs, and cocoanut crabs—and the scores of large turtles weighing on the average about 300 lbs each. The turtles formed our principal supply of fresh meat, furnishing us with delicious roasts, steaks, and soups.

The site for the station was selected in the midst of the cocoanut trees, at a distance of about 200 ft. directly east of the manager's bungalow, and just south of the east-and-west tramway. A few missing trees here and there afforded sufficient unobstructed sky for convenient adjustment of the eight groups of instruments.

A thick layer of sod covered the ground in the greater part of our camp. For our purposes this location had great advantages, for the vegetation would keep down the heat radiations, thus assuring us better "seeing," while the trees afforded some shade for our work and good protection for the instruments against vibrations from the wind.

The observing station of the Smithsonian Expedition was selected by Director Abbot at a point on the beach almost due

PLATE IV.



The forty-foot camera and two towers, one inside the other. The outer tower supports the upper end of the camera tube, the inner one supports the lens-board. During the eclipse the outer tower is covered with canvas to protect the inner tower from wind-vibrations. In the tent and resting on a concrete foundation is the plate-carriage.

east of the landing slip and about 1200 feet northwest of ours. He selected this location in order that he might have one-half the sky unobstructed by trees for his bolometric observations prior to the eclipse.

At the suggestion of the American consul at Tahiti it was planned to provide cocoanut-thatch huts for the living-rooms, dining-room, and kitchen. A remarkably small amount of material had to be taken along from San Francisco for this purpose. All that was required was some 3×3 inch side-posts, 2×3 inch cross-beams and rafters (a total of 160 ft. board measure of lumber for each hut), some nails, and a few balls of twine. Our carpenter and helpers built the frames. The natives wove the thatch from cocoanut fronds and tied or nailed it to the frames. The six living-rooms were each 10×14 feet, with side-walls $7\frac{1}{2}$ feet high. The dining-room, 12×28 feet, had thatch roof and gable, and mosquito-netting ceiling, walls and doors. The eight buildings, including a kitchen, were completed in four days. They were thoroughly adapted to their purpose, affording complete protection against the tropical Sun and rain, and adding greatly to our health and comfort during the stay of four weeks on the island.

While the huts were being built, the tents were put up, 300-odd packages unpacked, parts of instruments assembled in the tents, and the foundations prepared for the instruments. The Alt-Azimuth was the first instrument set on its pier and a time observation was obtained on the evening of the 11th. We were fortunate in having fine weather for the first ten or twelve days, and during this time all the instruments were placed in position and the preliminary adjustments completed.

On December 23rd Mr. Francis K. McClean, F.R.A.S., of Tunbridge Wells, England, and his party arrived on the steamer *Taviuni*, which had been specially chartered for this purpose. A few weeks before we left Mount Hamilton we had learned of their coming, and we were expecting their arrival with great interest. The party consisted of Mr. McClean, who was personally defraying the entire expense of the expedition, Messrs.

Brooks, Raymond, and Short, of Sydney, and Messrs. Winkelmann and Walker of Auckland. Mr. McClean also brought Mr. Merfield of the Sydney Observatory to assist our expedition. They located their camp immediately southeast of ours. We enjoyed their companionship greatly, and on several occasions joined forces with them in celebrations.

Although the weather was splendid during the first week, the latter part of the month was poorer than during the same time in the two preceding years. When there were no clouds, the sky was extraordinarily clear and blue, being entirely free from dust or smoke. Heavy tropical showers were frequent, but the water disappeared into the porous ground almost as quickly as it fell. The temperature was uniformly high, the mean at noon being 85° F., and at 9 P.M. 79° F. The range between day and night was as a rule less than 10°, and only once did the temperature drop as low as 72°.

January 3rd found everything in readiness for the important work of the day. All instruments had received their final adjustments and the observers had been trained to their work. The plates were "backed" and the plate-holders loaded the night before. The forenoon was clear the greater part of the time. Ten minutes before totality the writer set the plate-holder carriage in the forty-foot camera so that the crescent Sun fell upon the centre of the plate-holder, and started the clock which had been regulated to release the plate-carriage at such a speed as accurately to follow the Sun's image. Everything seemed then to be favorable, and yet, five minutes later a heavy rain was falling and all seemed lost. It was a tropical shower, in all respects like a large number of others which we experienced during our four weeks on the island, and having no apparent connection with the diminution of the Sun's heat on the approach of totality. The lenses and mirrors were hurriedly covered to protect them from the rain up to the time of the "second contact." After that time we decided to disregard their getting wet, for we were determined to get out of it what we could. Fortunately the clouds began to break one minute before second contact, the

rain slackened considerably, and ceased entirely a few seconds after the last traces of the Sun's limb had disappeared. During the first two minutes of the total phase the clouds became quite thin, though near the end of the second minute a thicker cloud passed over the Sun. During the last half of the total phase the sky was clear of clouds, but a thin haze could be distinguished. There was no wind.

Immediately after the end of totality we felt somewhat disappointed about not having had perfect weather conditions. We were certain that we had secured results worth all the trouble and expense to which we had gone, but we did not realize that almost the entire programme had been a complete success.

The eclipse was a very "light" one; everything in the camp and at some distance from the camp could be plainly seen. Dr. Campbell stated that it was not nearly so dark as those which he observed in 1898, 1900, and 1905. Totality began 27 seconds earlier than the time predicted by the American Ephemeris, and the duration, $3^m\ 52^s$, was 9^s shorter than the predicted duration. The times observed by Dr. Aitken without telescopic assistance, and by the observer inside of the forty-foot camera, agreed within a second, and were:—

Beginning $9^h\ 22^m\ 20^s$ Greenwich mean time.
Ending $9\ 26\ 12$ " " "

The discrepancy between the predicted and observed times is largely accounted for by errors in the ephemeris positions of the Moon. From observations made at Mount Hamilton in October and November, Professor Tucker had found that the Moon's right ascension was $0^s.41$ greater than the ephemeris value. This would account for fully 20 seconds of the advance in the predicted time. Additional slight errors in the adopted positions of the Sun and Moon and in the longitude of our station no doubt account for the remaining few seconds.

It is the custom of the Lick Observatory Expeditions to develop the negatives at the observing station if possible. When the *Annapolis* returned from Tahiti on January 1st, it brought an abundant supply of ice for photographic work. The Manager

kindly put at our disposal a room in his bungalow for use as a dark-room. On account of the high temperature it was not practicable to work in a closed dark-room for any length of time. It was, therefore, decided to do all the development at night when, in addition to the advantages of a somewhat lower temperature, the doors and window could be frequently opened for ventilation. Meanwhile the dismounting and packing of the instruments proceeded rapidly. The most valuable articles, such as chronometers, lenses, mirrors, prisms, and clocks were packed first, and, the surf being favorable, were put on-board-ship on the morning of January 4th. As soon as the last eclipse negatives were dry all were packed with extreme care and sealed in tin. These packages, accompanied by the observers in two surf-boats, were the last to go on board, at 11 o'clock of January 5th. By this time the surf had risen, on account of an approaching storm, one of the boats shipped considerable water, and the experiences of both boats in passing out through the surf were certainly exciting. The trip to Tahiti was accompanied with bad weather, and we arrived at Papeete at daylight on the 7th.

Preparations for an eclipse expedition is an intricate problem, requiring constant attention to innumerable details. The first plans are generally made a few years before the date of the eclipse. All available data are collected to aid in the choice of the most favorable location in the shadow-path—if there is any choice—and in forming a reliable basis for determining what supplies can be obtained at the station and what must be taken from home. Instruments must be designed, constructed, and thoroughly tested at home in order to insure their perfect working at the eclipse station. The construction and operation of a temporary observatory in a distant part of the world, away from machine shops, requires a complete outfit of tools and other items of supply. Every minute detail must be planned and arranged for in such a way as to require the least time and effort at the station. A neglect at home of a minor detail in the tests of a piece of apparatus will sometimes cause a loss of several days at the eclipse station. An eclipse observer takes nothing for granted

in his preparations. Considerable attention is given even to such an apparently simple matter as "packing," and the value of this precaution was greatly appreciated by every member of the expedition during the few days on Flint Island, and eepecially at our first meal. The extensive experience which Director Campbell has had in the organization and management of eclipse expeditions made itself evident to the younger members at every turn.

It would indeed be a serious omission not to mention the invaluable service rendered to the expedition by the chief of our commissary department. During our four weeks' residence on Flint Island every member of our party was well all the time, notwithstanding exposure to tropical sun and drenching rains. I say this not boastingly, but in acknowledgement of the thoroughness with which our changing needs and every detail of our comfort—not to mention a series of celebrations as a relaxation from our strenuous toil—were provided for. We were indeed "a happy family" under the care of Mrs. Campbell.

The accompanying views of the station are from photographs secured shortly after the eclipse was over. The negative of the group of observers was unfortunately much underexposed. The outer tower supporting the tube of the forty-foot camera had a canvas covering as a wind protection for the inner tower, which supported the lens. This covering had been removed before the photographs were taken.

Following is a brief description of the various instruments and of the results obtained with each. The times of beginning, ending, and duration of totality have been given above.

Latitude and Longitude.

It was the intention that Dr. Aitken should observe Moon culminations both before and after the full Moon of December 19th, with the Repsold Alt-Azimuth instrument, to determine the longitude of the station; taking into account the fact that the Moon's right ascension, as measured at Mount Hamilton on four nights in October and November by Professor Tucker, was $0^{s}.41$ greater than the ephemeris value. Unfortunately, thick

clouds at the times of transit on some ten successive nights seriously interfered with the work, and only one culmination was observed,—on the night of December 25th. The adopted value of the longitude is the weighted mean of the values obtained from this Moon culmination, from two chronometers which were transported from the clock of the Students' Observatory, Berkeley, to Flint Island and back to the clock in Berkeley, and from a comparison of time observations made on Flint Island on January 3rd and at Point Venus, Tahiti, on the 8th. The latitude was obtained from observations of meridian altitudes of a considerable number of stars on two evenings. The resulting values for the co-ordinates of the instrument, located near the centre of the groups of instruments, are :—

Longitude $10^h\ 07^m\ 13^s$ W. $\pm 4^s$
Latitude $-10°\ 25'\ 26''.8$ $\pm 0''.4$.

The Forty-Foot Camera.

The forty-foot camera is excellently adapted for obtaining photographs of the corona on a large scale. For this purpose the tower form of camera is much to be preferred to the horizontal forms with cœlostat to reflect the coronal radiations into them. The task of constructing and erecting the two supporting towers is not as laborious a task as one might suppose. On this occasion, on account of the high altitude of the Sun at the time of totality, the towers had to be the full 40 feet in height. Nevertheless, they were constructed by Dr. Campbell and the carpenter in less than two days, and a few hours, with the help of the natives, was all the time required to erect and set them into their positions.

In this form of camera the lens is stationary, while the plate-holder is made to follow the image of the Sun on an accurately curved metal track.

Six negatives were secured with the forty-foot camera. The seeing was very good, the focus and clock-driving were perfect, and the negatives are excellent. A reproduced copy of the negative of 16 seconds' exposure is reproduced in the illustration.

It is needless to say that the wealth of detail of the original is largely lost in the half-tone print. It is unfortunate that astronomical photographs of this kind cannot be reproduced satisfactorily.

It is beyond the scope of this article to give a detailed description of the corona. On the long exposure negative about thirty streamers are recorded with a length greater than a solar diameter, and half that number extend to a distance of one and a half solar diameters. A considerable area to the east of the Sun seemed to be a region of exceptional coronal disturbance. Several prominences are recorded, one especially large one in the south-west quadrant.

The Floyd Camera.

The forty-foot camera, on account of the large scale of the images (the Moon's diameter was 4·74 inches) is especially suited for recording the wealth of detail in the inner corona. For the study of the outer corona a camera of shorter focal length is more efficient. For this purpose a camera with a Clark lens of 5-inch aperture and 67-inch focal length was used. It was mounted horizontally so as to receive its light from the same mirror as the large moving-plate spectrograph. The entire work of mounting and adjusting was done by Dr. Campbell. The exposures, eight in number, were made on eclipse day by Mr. Mortimer, the new manager of the plantation, who arrived on Flint Island about the middle of December. The negatives are of great excellence. They show the general form of the corona beautifully, and record streamers equal in length to two diameters of the Sun. The negative of 16^s exposure is shown in the reproduction, but the exquisite detail of the original is lost.

The Moving-Plate Spectrograph.

The spectrograms obtained at the eclipses of 1898, 1900, and 1905, on a continuously moving plate, showed that this is a most advantageous method for recording the changing spectrum of the Sun's edge as the edge is gradually covered or uncovered by the Moon. The dispersive power was supplied in 1898 by a

plane grating, and at the other eclipses by two 60° prisms. The instrument used at Flint Island is shown in the illustration. The light, supplied by a part of the cœlostat mirror, passed through three 60° prisms, whose circular apertures are 2⅛ inches, and thence through the camera lens of 60-inch focus, to the plate. The cœlostat may be seen, in the photograph, under the camera-box section of the spectrograph, and the first prism is visible to the right of the cœlostat. The entire spectrograph was so mounted that it could be rotated about the axis of the light-beam incident upon the first prism-surface, in order to place the prism-edges parallel to the central elements of the uneclipsed thin crescent near the beginning and near the ending of totality. The central sections of the crescents in the cœlostat images made angles of 27° 06′ and 6° 18′, respectively, with the horizon. The instrument was placed in its computed position by means of a theodolite, and the spectrum on the day of the eclipse fell upon the sensitive plate in the desired position, as nearly as could be estimated.

Immediately in front of the plate was a slit $^1/_{16}$ inch wide, which permitted the central section of each crescent in the spectrum to fall on the plate. A motion of approximately $^1/_{16}$ inch per second was given to the plate by the piston on the plate-holder slide. The piston was operated by a weight.

The linear dispersion is such that the region λ 3700 to λ 5300 covers 13 inches. The focal surface is strongly curved; the tangent at the center of the field lying ¾ inch outside the focal positions at the ends. A film 7 × 14 inches was used. A special plate-holder held the film firmly in position.

An exposure extending from fifteen seconds before to fifteen seconds after totality began was planned for, but omitted on account of the rain. The mirror was not uncovered until some five seconds after totality began. A corresponding exposure was made at the end of totality, with entire success, save that the negative is somewhat overexposed. The photograph is in good focus, from λ 3800 to λ 5100. Hundreds of bright lines are

PLATE V.

Moving-Plate Spectrograph (large instrument in foreground) and Floyd Camera (horizontal and to right of centre). Both instruments received their light from the coelostat, seen under the camera-box section of the spectrograph, about half-an-inch to the left of the centre of the picture. The Plate-holder was moved in the slides by a piston operated by a weight. Piston and weight show in picture.

recorded in length and at times showing the thickness and locations of their corresponding vapor strata, and their changes into dark lines as the photospheric surface was uncovered by the Moon. The photograph contains a mine of information as to the structure and composition of the Sun's higher atmosphere. The series of four photographs may be said to constitute the basis for the study of the stratification of the Sun's atmosphere.

The Smaller Spectrographs.

A spectrograph with three dense glass prisms was used in the hope of recording the green coronal line, in order to determine its wave-length with great accuracy. Unfortunately this spectrogram was not successful, undoubtedly because of the strong absorption of the prisms. Two one-prism spectrographs were also used on account of their efficiency in recording the continuous spectrum of the corona. With one of these the exposure was made on a Seed's plate No. 27 for the blue and violet region, and with the other on a Cramer's Isochromatic plate for the green and yellow regions of the spectrum. Both were entirely successful, the spectrum for the inner corona being recorded from λ 3600 to λ 5350 on one plate, and to λ 6000 on the other, all in good focus. The bright line in the green and one in the ultra-violet are shown on the plates, but all other bright lines seem to be lost in the strong continuous spectrum of the corona, the dispersion being low. From measurements of the spectrogram on the Isochromatic plate the value λ 5301·4 was obtained for the green bright line, and this value is probably correct within ½ Angström unit. The spectrum of the inner corona appears to be free of absorption-lines. The absorption-lines show very faintly in the spectrum of the outer corona and still more faintly in the Moon's area. The dark-line spectrum is relatively weaker than on the spectrograms secured in Sumatra (1901) and Spain (1905). The maximum intensity in the continuous spectrum is perceptibly further to the red of the maximum in the solar spectrum obtained with the same instrument,—plainly signifying a lower effective temperature in the corona than in the Sun.

THE QUARTZ SPECTROGRAPH.

Professor Lewis's large quartz spectrograph, provided for his researches by the Carnegie Institution, was efficient for recording and determining the accurate positions of coronal bright lines. A Schrœder's metal mirror, belonging to the Lick Observatory, mounted on a clock-driven (at one half the diurnal rate) polar axis, reflected the light horizontally into the quartz image-lens. The collimator- and camera-lenses of quartz are of 9·2 cm. aperture and one meter focus. The effective rectangular apertures of the two Cornu quartz prisms are $6 \times 6{\cdot}8$ cm. The length of the spectrogram from D to λ 3000 is 14 cm.

The slit was adjusted to tangency to the Moon's limb at a point 16° 42′ north of the highest point of the image on the slit, as this was the mean of the positions of tangents to the two points of contact of the Sun and Moon.

It was intended to obtain a spectrum of the first flash, but the rain prevented.

The exposure on the coronal spectrum extended from $0^m\ 15^s$ to $3^m\ 30^s$. The photograph shows a strong continuous spectrum extending from λ 3200 to λ 5100. Here and there in the middle ultra-violet, and nowhere else, are very faint indications of superimposed dark-line spectrum, of the same width as the continuous spectrum. This width is 3·1 mm. Superimposed on the continuous spectrum are about twenty-five sharp lines, none of which appears to proceed from the chromosphere. Some are so faint that their existence may be doubtful, while others may be maxima due to the superimposed dark-line spectrum. Two rather strong bright-lines appear to be new. Dr. Lewis further finds from the photograph that the Sun is relatively much richer in ultra-violet light than the corona, from which fact the much lower effective temperature of the latter is safely inferred.

The west limb of the Moon was made tangent to the slit just at the end of totality, and an exposure on the flash spectrum,—overexposed on account of the duration of totality being shorter than expected,—recorded the tips of some eighty strong, bright crescents projecting beyond the solar spectrum.

THE INTRAMERCURIAL-PLANET CAMERAS.

The fact that the major axis of the orbit of Mercury is turning slowly without the existence of any known body or bodies that could produce this motion, under the application of the Newtonian law of gravitation, gave rise to the search for an unknown planet whose orbit would be smaller than the orbit of Mercury. Such a planet would have escaped detection on account of its constant proximity to the Sun. An effective search can be made only at times of total solar eclipse. Accordingly search has been made for this hypothetical planet—to which the name "Vulcan" has been given—at every opportunity since the eclipse of 1900.

On Flint Island this search was again to be made, and, if possible, brought to a close. The instruments used for this purpose were essentially the same as those used by Dr. Perrine at the eclipses of 1901 and 1905. Four cameras, provided with lenses of 3-inch aperture and 11-foot 4-inch focal length, were fastened together rigidly, and so mounted on a clock-driven polar axis that together they covered a region 28° long, in the direction of the Sun's equator, by 9° wide. Another set of four cameras was similarly mounted, so as to take in the same region of the sky as the first group. Both groups of these cameras, and the group of polarigraphs, are shown in the illustration.

One plate was exposed in each camera during the last three minutes of totality. Duplicate exposures were thus obtained for each of the four areas into which the region was divided. One of the groups of cameras was set up on Mount Hamilton in October, before starting to Flint Island, and duplicate exposures of precisely the same region were obtained after sunset. The four sets of negatives furnished sure and convenient means of determining whether objects on the plates were stars, planets, or defects.

Dr. Perrine has made a preliminary examination of the Flint Island negatives, and finds that during the available three minutes during the eclipse the images of fully 300 stars were

recorded, down to the ninth magnitude. All the images have been identified as those of well-known stars. Dr. Perrine's work at the eclipses of 1901, 1905, and 1908 makes it improbable that a planet as bright as the 7th magnitude exists, and a large number of planets as faint as the 7th magnitude would be required to provide sufficient mass to account for the observed disturbance in the orbit of Mercury. It seems probable, therefore, that the observational side of the famous intramercurial-planet problem has been definitely brought to a close. According to the recent mathematical researches of Professor Seeliger, the material responsible for the Zodiacal Light exists in sufficient quantities to explain the anomalies in Mercury's motion. This is at present the only explanation that we have for the disturbance.

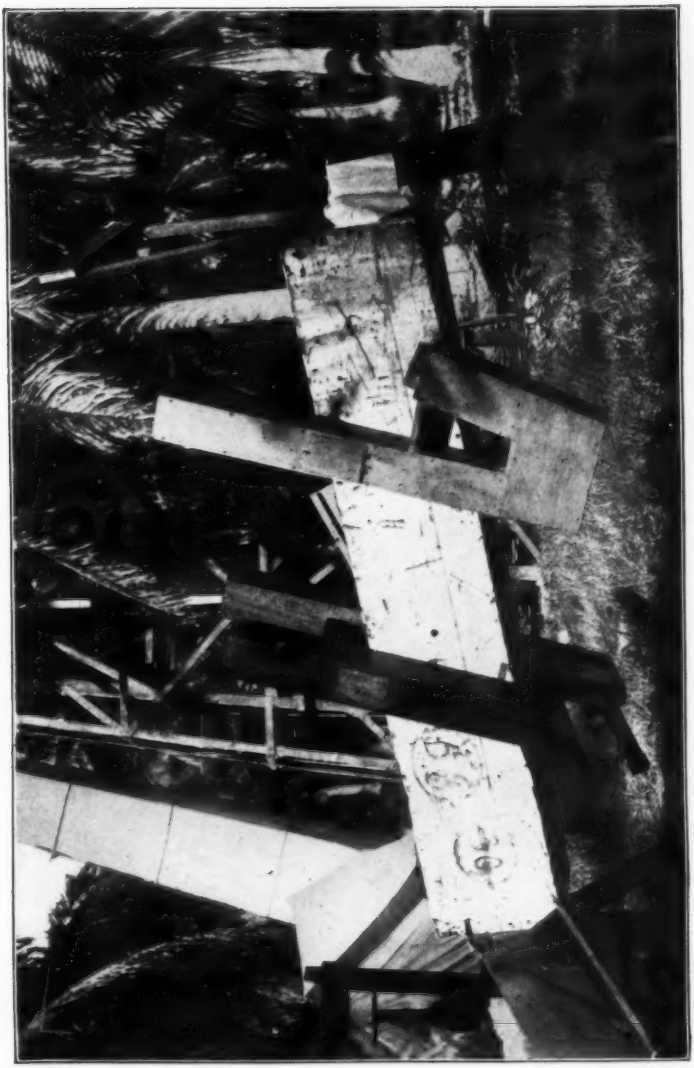
The Polarigraphs.

Four cameras mounted on a clock-driven axis were used by Dr. Perrine to study the effects of the polarization in the coronal light. One of these had a double-image prism, and two had plane-glass reflectors in front of the objectives to serve as analyzers, while the fourth was to secure an unpolarized image of the corona as a standard of comparison. The plane-glass analyzers were set at the angle of maximum polarization. Their principal axes were adjusted, one parallel to a north-and-south line and the other to an east-and-west line, through the corona.

The performance of all the polarigraphs was exactly as planned. Mrs. Campbell and Mrs. Dreher assisted in making the observations. The four series of negatives, with exposures of from 2^s to 60^s, appear to be perfect in every respect. They show strong polarization effects in the corona, perhaps even to the very edge of the Moon's image. All of our previous polarization observations were secured through clouds; but, so far as we may judge from a comparison with the present series, the clouds were without appreciable effect on the character of the images.

It is hoped to make accurate photometric observations of the polarization series of photographs.

PLATE VI.



The polar-axis carrying the three-prism and two one-prism spectrographs. Portion of 40-ft. camera and towers in background.

PLATE VII.

Two Sets of Intra-Mercurial Cameras (to the left of the centre), and the polar graphs on the polar-axis to the right. This picture shows the driving-arm, sector, and clock for each of the three axes.

PLATE VIII.

Concave Mirror and Bolometer of the Smithsonian Institution Expedition.
Director Abbot to left, Mr. Moore to right.

The Photometer.

Mounted on the same axis as the polarigraphs was a photometer, in all respects resembling an ordinary camera with the lens removed. The light from the corona and surrounding sky passed directly through the aperture to the photographic plate. Two plates were exposed when the sky was entirely clear of clouds. Small standard squares on the plates had been exposed to the light of the Hefner lamp on the preceding night. Using these standards as a basis of comparison, it should be possible to obtain a satisfactory measurement of the total effective photographic action of the coronal radiations. These plates contain the data for measuring the sky brightness surrounding the corona. Dr. Perrine's examination of the negatives shows that the effective photographic radiations of the corona came almost wholly from its extreme inner parts,—from within 1′ or 2′ of the Sun's surface.

ANCIENT ICE AGES AND THEIR BEARING ON ASTRONOMICAL THEORIES

By A. P. Coleman

EVERYONE is familiar with the general features of the last, or Pleistocene, ice age, which covered with its glacial sheets all of Canada except the Yukon region and extended as far south as Cincinnati in the United States. Its causes were of world-wide operation, for we have evidence of great ice sheets in Europe and Patagonia, and of the refrigeration of lofty mountains in all parts of the world. Even under the equator in Africa and the Andes the higher mountains showed greatly extended glaciers as compared with the present.

There was, however, a much more impressive glaciation in late Palæozoic (Permo-carboniferous) times, when large parts of India, Australia and South Africa were covered with ice sheets, whose ancient boulder clay, now transformed into solid rock, covers hundreds of thousands of square miles and extends even into the tropics on all three continents. In many places these glaciers reached sea level. This refrigeration was specially severe around the present Indian Ocean, and only small evidences of glaciation have yet been found in other regions, such as South America, Russia and Prince Edward island.

Within recent years a third ice age has been brought to light in early Cambrian or late Pre-cambrian times, once more having its greatest development in Australia and South Africa, but found also in India, China, the Lake Superior region and in Scandinavia.

Within the last two years the present writer has obtained strong evidence of a great ice age in still earlier times, at the base of the Huronian. A wide-spread boulder conglomerate of the Huronian has been observed at dozens of points across northern Ontario, in Quebec and in Keewatin, and also in the United

States south and west of Lake Superior. This boulder conglomerate has all the characters of a consolidated boulder clay and is exactly like the Permo-carboniferous Dwyka conglomerate of South Africa. It contains boulders of all sizes up to tons in weight, and of kinds that must have been transported long distances, embedded in an unstratified matrix. A few striated stones have been worked out of the matrix, as characteristically glaciated as those from our Pleistocene boulder clay, but one needs patience to extract them.

Every form of evidence relied on to prove the work of ice in Permo-carboniferous or Pleistocene times is at hand in this Huronian formation; except that up to the present no polished and scratched surfaces have been found on the rock beneath. This is no argument, however, against its glacial origin, since the same is true in many cases beneath the latest boulder clay, and also under the southern part of the South African Dwyka conglomerate. Such a boulder-bearing conglomerate found from point to point over a distance of 1,000 miles from east to west and 750 from north to south cannot be accounted for in any other way than by glacial action.*

From the outline just given it will be seen that there have been four times of great refrigeration, when ice was at work over immense areas which now have temperate, or even tropical climates. Between these widely separated Glacial Periods the climates seem to have been mild even into the polar regions, as one can prove from the fossil trees of Greenland, for instance.

The oldest of the ice ages goes back to the most ancient geological times, for the Lower Huronian has only one older formation beneath it, the Keewatin. There is evidence then that ice sheets could exist on a large scale almost as far back as the geological record reaches. The Huronian region, which now has hot summers, was then covered with glacial ice like that of Greenland, and was evidently much colder than now.

The bearing of the geological evidence given above on the history of our earth as a planet must be clear to every astronomer.

* *Jour. Geology*, 1908, pp. 149-158.

If the earth supported an immense ice sheet in the early Huronian there is no geological evidence whatever in favor of the usual form of the nebular theory. The earth has not been cooling down during the 100,000,000 years or more since the beginning of the geological record; and if it was ever molten its cooling must have been practically complete before the earliest known rocks were formed. All the speculations as to its early history so seductively unfolded by Mr. Lowell, for instance, from his study of Mars fall to the ground; and his depressing predictions as to its future are probably equally baseless.

We must also give up Sir George Darwin's brilliant theory of the origin of the Moon by tidal action, unless the whole process is pushed back to times much more remote than he has assumed.

The whole series of hypotheses respecting the age of the Sun and of the earth, as formulated by Lord Kelvin and Mr. Tait, founded on physical and astronomical assumptions as to the supposed rate of cooling of these bodies, must be dropped.

Fortunately new sources of heat, in radioactivity, work done in condensation, etc., are now available to account for the Sun's high temperature and the warmth of the earth's interior, so that the supposed cooling down may never have taken place. These bodies may even be in process of warming up, though more probably they maintain a somewhat even temperature, perhaps with cyclic ups and downs.

The fact that widespread glacial action occurred at four times, separated by long intervals, rather suggests some recurrent cosmic cause; but the usual hypothesis of the production of ice ages at periods of great eccentricity of the earth's orbit, as worked out by Croll and amended by Ball, does not seem to fit the geological facts, for two reasons. It provides for too many ice ages, and it makes the glaciation alternate in the two hemispheres. The greatly increased glaciation on mountains under the equator in Africa and South America cannot be accounted for on the theory of alternation between the two hemispheres, which would leave the equatorial regions untouched.

Suggestions as to the causes of ice ages have included several other astronomical factors, such as a shifting of the poles of the earth, an important decrease of the Sun's heat, the passage of the solar system through colder parts of space, etc. Geologists in general attach little value to these speculations, since direct evidence of the implied conditions has not yet been supplied; and incline to assume some general terrestrial cause, such as a change in the amount of carbonic acid in the atmosphere, or certain local causes, such as changes of elevation, deflecting of ocean currents, or the shifting of centers of high and low atmospheric pressure. Perhaps the most satisfactory account of the causes of ice ages is eclectic, combining two or more of the theories suggested above.

The meteoritic or planetesimal theory of the origin of the earth seems on the whole most satisfactory to geologists, as solving the widest range of difficulties in regard to ancient climates; and it is desirable that astronomers should consider how far this theory can be made to replace the usual form of the nebular hypothesis. Astronomers should certainly not ignore the undisputed proofs of profound glaciation toward the end of Carboniferous times, and the very probable ice ages in early Cambrian and lower Huronian times, as has recently been the case in a series of popular articles by an astronomer of good repute. The well-established history of the earth, as furnished by geology, goes back many millions of years and should be given due weight by astronomers in shaping their theories as to the origin of the solar system.

THE APEX OF THE SUN'S WAY

By John A. Paterson

"All things move,
Each sun flies forward to his brother sun,
The dark earth follows wheeled in her ellipse."

THERE lies embedded in these lines three astronomical or physical truths,—Newton's first law of motion, Herschel's theory which is the subject of this paper and Kepler's first law. A body once in motion, unless acted upon by some force, will continue in motion in a straight line with uniform velocity. An uninstructed and non-philosophical mind will assume that rest is the natural condition of a body in nature ; but that is not so, there is no rest in nature unless in death, and even then there is an active disintegration of elements working constantly through chemical and physical changes. Our hearts beat all our lives, our lungs expand and contract from the cradle to the grave unceasingly ; movement, constant restless movement, is the law of nature from the molecule that has existence and no magnitude, running to and fro in its little sphere, to the mighty Sirius or the giant nebula that flames and heaves in the immensity of space, whole universes of world-systems distant from us. In fact rest is in the nature of things an impossibility. The universal law of gravitation encloses everything in its net-work, it is the immutable will of the Deity, and it forbids rest, it decrees restlessness and all things submit to its sway. If there were but one body in nature we might have absolute rest, but if there be two, even if ever so far distant from each other, there must be motion. For under the law of gravitation they would commence to move toward each other in a straight line with accelerated velocity, at perhaps a fraction of an inch in a million years and then by ever-quickening steps creeping onwards, ever onwards, until as distance decreases velocity increases, and they would

clash together. If there were only three bodies in the universe the problem would become complicated, revolutions would be set up, orbits established, conic sections carved out of space and multifarous dynamic problems would present themselves for elucidation. In our early schooldays we were taught that the earth had two motions, one round its axis in 24 hours and another round the Sun in 365¼ days, but since then we have learned much more than that as to Mother Earth's movements, and we have discovered by long and patient observation, that our august parent has at least 12 different movements showing a most complicated and varied programme of disturbance.

I. It has a movement of rotation about its axis. In virtue of this a point at the equator moves 1,171 feet per second.

II. It has a movement of translation about the Sun of 18 1-3 miles per second.

III. The conical motion of the axis of rotation in 25,765 years produces the precession of the equinoxes.

IV. The monthly movement of the earth about the center of gravity of the system of earth and moon.

V. The motion of nutation of the earth's axis has a period of 18 1-2 years.

VI. The obliquity of the ecliptic (23 degrees, 27 minutes) varies at the rate of 47 seconds per century.

VII. The eccentricity of the earth's orbit varies in cycles of long period.

VIII. The longer axis of the earth's orbit revolves in a period of 21,000 years.

IX. The perturbation of the motion of the earth by the combined action of all the planets may be counted as a single effect, though it is, of course, the sum of several partial ones.

X. The earth moves about the center of gravity of the solar system, not about the center of figure of the Sun, and the place of this center changes as the configuration of the planets changes.

XI. The earth, with the whole solar system, has a motion of translation through space. The rate of motion is about twelve miles per second.

XII. The axis about which the earth rotates is perpetually changing its place with respect to the surface of our planet. The amount of change of the pole is small, hardly more than 40 or 50 feet, but it shows itself as a regular periodic change in the latitudes of terrestrial stations.

It is this Eleventh movement we are to speak of to-night, the drift of this earth with her sister planets, the whole solar family in fact, through the limitless fields of azure space. When

this thought was first presented in a clear and definite form by Sir W. Herschel in 1783 (although Lalande had hinted at it in 1776) the scientists of the day looked dubious, and Burckhardt and Bessel undertook to disprove his theory. Considering it with the light of a century and more of investigation it is difficult to understand how the Sun's system could be stationary. The law which keeps the members of the system moving could not very easily refuse to govern the system as a whole. Our system is encircled by other sun-systems; it is one of a vast cluster, and the universe is filled with clusters. The Sun attracts the earth, the earth attracts the feather from the linnet's wing as it floats earthward, and it would be strange indeed if the great orbs throughout space, distant though they may be, were not to attract our sun and his planetary retinue, and equally strange if our sun did not exercise some attraction over other systems. Gravitation reaches out her puissant arm universally, and with her unrelenting hand grasps everything everywhere and plants her throne of empire throughout the infinite, and so it shall be until time shall be no more. There would be one chance in many millions that the attraction of orbs around us would counterbalance and hold the Sun and his planet-family in equilibrium. So exquisite a balancing might be possible for an instant, but the attracting forces emanating from the other orbs would soon change their situation, the directions of these attractions also would change, and the system at rest would soon be set in motion, and once in motion would never stop; and so we are guided through space with the swiftness of an angel's wing, and unerringly steer our way through black depths with beacon lights in front guiding us onward, and lights behind to show whence we have come during the remote æons of time not counted save in the chronology of heaven. It seems infinitely improbable that there should be any fixed material particle in the whole universe. And, in fact, it has been demonstrated by Laplace that a system of bodies, such as the solar system, placed in space and submitted to no other continued force, except the reciprocal attractions of the bodies which compose it, must either

have its common center of gravity stationary or be in a state of uniform rectilinear motion. Thomas Carlyle's vigorous prose becomes by its very virility poetic, and even more than that, not only poetic but scientifically true, when he reminds us, in his *Sartor Resartus*, that by throwing a stone and so changing its place and therefore the effect of its weight, he thus shifts the centre of gravity of the Universe.

Our system is ringed by an immense emptiness; the nearest fixed star to us is *Alpha Centauri* from which a beam of light travelling at nearly 200,000 miles a second takes four years to pass, and throughout that gigantic immensity we rush onward. To bring this condition to an everyday observation,—if we were to imagine the solar system confined within the breadth of a street in the city of Toronto running north and south, the Sun being in the center and the orbit of the remotest planet skirting the east and west edges of the street, then on that scale there would be no orb between that position and fifty-seven miles east, and as many miles north and south and west.

When we think of the almost immeasurable intervals between the different sun-systems we then get the impression of an awful loneliness, as if, indeed, they were islands separated by vast stretches of dark and empty space, floating in an ocean of ether across which the waves of light illimitable and gravitations innumerable pulsate and bind together the most distant stars. Light is the magnificent go-between; it is the universal language among the solar families; the spectroscope is the page on which the ray writes its message; and Fraunhofer's lines are the letters that there are blazoned. There are no *fixed* stars. The name "fixed" is an archaism, it is unphilosophic, it is untrue; there is nothing fixed in the Universe. It is ever progressive, and yet no age darkens it, no stains of time mar its architecture. Our earth moves in its orbit at the rate of eighteen miles a second; many stars move more than forty miles a second. The runaway star Groombridge (1830) races at two hundred miles a second; it is a million times further away from us than our sun and it would take 250 years to traverse an arc of the sky equal to the

diameter of the Moon and that would hardly be noticeable. Scientific and mechanical ingenuity have worked out wonderful instruments of precision. The meridian circle can measure an angle subtended by six inches at a distance of eighty miles, to such a degree have appliances at our disposal been refined for making accurate determinations. We are thus enabled to detect the movements of many stars and to obtain their angular rate of motion. With an optical instrument we can take cognizance of that part of the star's motion which is perpendicular to the line of sight. If the star is coming directly towards us or receding directly from us, then the telescope offers us no help, but Doppler's theory and the spectroscope enables us to calculate the rate of such a movement. When the body is coming towards us the dark lines of the color-band are shifted towards the blue end, when the body is moving away from us the same dark lines are displaced in the opposite direction, and by careful measurement the rate of movement can be calculated. If we stand in the dark on a road, and a man is walking some distance ahead of us with a light, it would be impossible to tell whether he is approaching us or receding from us, but on the other hand if a star millions of miles away is ahead of the earth moving in her orbit, the astronomer can tell by the spectroscopic lines whether the star is moving towards us or moving from us.

The problem then is, to ascertain the movement of the Sun and his system through space and to measure that displacement. Any direct observation we may make of the Sun himself cannot avail, for we move with him; our fortunes for better or worse are fixedly linked with him. Like a great Admiral he guides his fleet of planets, satellites, meteors, comets and planetoids through the ocean of space without a jar to wake the tiny fledgeling swinging in its nest on the bough, and without a tremor to empty the chalice of the harebell of its beads of dew. In the language of a well-known ancient poem we may say of the Sun, and each member of his royal retinue may say to the other, "whither thou goest I will go, and where thou lodgest I will lodge, and where thou diest I will die and there will I be buried.

Naught but death shall part thee and me." If we could remove ourselves from the earth and plant ourselves on some member of another system and watch the Sun with a meridian circle there would be possibilities open which are closed under present conditions. Points of reference can only be provided by the stars, fixed as we are upon this globe; but here lies a fundamental difficulty. When we are in a railway train and wish to judge of the rate and direction of its progress we compare ourselves with the telegraph poles as they seem to shoot backwards, but suppose the poles themselves were in motion, how would we know the direction and rate of our progress? If there were only a few stars and these in motion, the solution of the problem would be well-nigh impossible, the proper movements of these stars and the movement of the Sun would be blended inextricably, but when we consider that the stars are in thousands we can then apply the principle of averages,—there is safety in a multitude. If all the stars were parallel in direction of movement and equal in velocity then they would be useless as guides, but there is safety not only in the multitude of objects but in the infinite variety of their directions.

It is a striking paradox to propound, that because the movements of the stars are irregular, both in direction and magnitude, the results derived from the observations are the more valuable. In such a problem we must depart from any idea of close and rigid investigation, because it is impossible to apply those perfect principles of pure mathematics which hold sway in the domain of the calculus, whereby the most exact results are deduced without the most infinitesimal error. On applying the principle of averages, we assume that the stars which form the elements of observation are fixed beacon lights, and we enquire what changes would be presented if our Sun were the only moving body. The method of least squares is a new engine of observation, and has become an important handmaid in the discovery of physical truth. It is, in short, a method of obtaining the most probable value of a quantity from a set of observations made to determine it, in accordance with the principle that the

sum of the squares of all the errors is to be made a minimum. We may set aside as beyond the reach of our discovery the deduction of the form of the orbit in which the Sun possibly revolves. Doubtless if our observations had extended over millions of years we might possibly discover something more or less accurately with regard to movements so stupendous, but upon the data that have been so far presented to the astronomer, only actual rectilinear motion has been made out. The Sun no doubt moves in a curve of some sort, but the time of the observations has been so comparatively short, although extending over 100 years, that we have only discovered the direction of the tangent to this immense solar curve. Let us simplify the problem by a familiar illustration. It is an old astronomical axiom that the Sun is the astronomer's chair, and for this problem we must regard the astronomer as stationed at the Sun. The distance of our earthly habitation from the Sun being only a trifle of 92,900,000 miles or thereabouts is to be disregarded, and we must suppose ourselves making observations from the heaving mass of fire that appears to make up the solar envelope. If we were on a ship approaching the harbor, and on the shore were two lights situated at a distance from each other, the line joining them being perpendicular to the line of approach, as we come nearer the harbor these two lights which at a distance out at sea would appear to be somewhat close, would gradually appear to recede one from the other and open up. Again, consider the converse case. Let the ship be approaching the harbor on one side of a lake, while directly behind, on the opposite side of the lake, lights are posted. When we were near those lights they appeared to be wide apart, but as we progress they seem to become closer one to the other ; and the captain, by repeated observations from time to time of these two appearances,—the lights behind and the lights in front,—could fix his rate of progress and the direction of his motion. It is thus with the movement of the ship of the solar system through the ocean of space. The lights or stars in front seem to grow further apart, while the lights or stars behind seem to grow closer as we leave them. The problem is then to find the

point from which the stars seem generally to recede or diverge, and also the point towards which the stars in the other direction seem generally to converge. The firmament, as we have said before, supplies us with numberless lights, and we must by the method of averages put ourselves in the position as if the stars towards which we are moving were stationary as the lights on the shore, towards which the supposed ship is moving and also as if the stars from whose direction we are receding are stationary as the lights upon the shore from which the supposed ship is moving. To use a still more familiar illustration; when we approach a forest the trees though at first seeming close together, an impenetrable tangle, soon open up and stand apart with spaces between. It is thus also as our solar system approaches the star tangle in front the clusters open up more widely and conversely, because in the course of years these galaxies do open up, therefore we conclude that our solar combination moves forward towards the openings.

Let us from another standpoint present the theory of solar movement. Almost all the great discoveries in astronomy have resulted from consideration of the great principle of the residual phenomenon of a numerical kind, that is to say, of such portions of the numerical results of observation as remain outstanding and unaccounted for after allowing for all that would result from known causes. The great discovery of the precession of the equinoxes resulted as a residual phenomenon from imperfect explanations of the return of the seasons by the return of the Sun to the same apparent place among the fixed stars. So also aberration and nutation resulted as residual phenomena being that portion of the change of apparent place of fixed stars left unaccounted for by precession. The apparent proper motions of the stars are the observed residual phenomena, outstanding and unaccounted for by a strict calculation of the effects of precession, nutation and aberration. When causes are explained to the core and theories are perfectly propounded and illustrated, then the residual phenomena are diminished to zero, which is another way of saying that there remains nothing to be explained or accounted

for,—the problem is completely worked out and nothing is unknown.

The proper motion of the Sun being suggested as another cause to account for the apparent changes in fixed stars not already accounted for by precession, nutation or aberrration, we have two things to be disposed of,—(1) the direction of the motion ; (2) the rate of motion.

This principle of residual phenomenon is illustrated in solving the problem of the three bodies, the celebrated crux of the mathematical astronomer. Turning to the lunar theory, as a concrete example, let us consider the equation for the Moon's longitude. It consists of seven terms, and each has its own physical interpretation, that is to say, the algebraic expression in indicating where the Moon ought to be, as to longitude, is interpreted by an appeal to physical causes until these residual phenomena are reduced by successive explanations to zero. These seven terms are :—

(1) The uniform angular velocity,
(2) and (3) The elliptic inequality or equation to the center,
(4) Evection,
(5) Variation,
(6) Annual Equation,
(7) Reduction.

If out of these seven terms five only were explained from physical causes, then two would depend on undiscovered physical causes, which the astronomer would have to satisfy, and so if the sixth were discovered there would remain the seventh as a residual phenomenon, and on that being discovered the whole problem would be complete.

Sir William Herschel was the pioneer in the solution of the solar problem, and to him is due the expression,—"Apex of the Sun's way." In 1783 he made observation of the proper motions of such stars as could be tolerably ascertained, and from these he fixed the apex as near λ *Herculis*, R. A. 260° 24′ and D. 26° 3′. Argelander in 1838 fixed it as R. A. 259° 51′ and D. 32° 30′. Otto Struve in 1841 fixed it as R. A. 261° 21′ and D. 37° 36′.

Galloway at the Cape of Good Hope, observing the southern stars, fixed it as R. A. 260° and D. 34° 23′. In all these elements of uncertainty the problem is no summer-night amusement. It demands the highest reach of genius, and the philosopher who attempts it, if he cannot attain absolute success, may even do better, for he may deserve success.

Otto Struve classed the distances of the stars according to their magnitude or apparent brightness, and instituted separate and independent calculations for each class, including stars assumed to be equi-distant. Argelander, on the other hand, classed them according to the observed amount of their apparent proper motions, on the presumption that those which appear to move fastest are really nearest to us. Oscar Stumpe, of Bonn, in 1890 made observations of 1,054 stars and deduced the apex to be as follows :—R. A. 279° and D. 40°. The mean of 30 observations by about twenty-five astronomers between 1783 and 1890 gives as an average R. A. 269° and D. 35°. The apex of the Sun's way thus can be shifted hither and thither by the admission or exclusion from the research for its position of stars with large proper motions. The line must be drawn somewhere. By general agreement the "runaway stars" are barred, such as 1830 Groombridge, that has a velocity of 200 miles a second or an annual motion of seven seconds of arc, and 61 *Cygni*, that has an annual motion of five seconds of arc, being 37 miles per second. 1830 Groombridge is a remarkable star and cannot remain a member of the visible universe. It is a visitor, flying through space with a velocity which the combined attraction of all the stars could never stop. Professor Newcomb puts it thus : The number of the stars visible in the most powerful telescope would be say 50,000,000, put them at 100,000,000. The average no doubt would be equal to five of our Suns. Let them be spread out in a layer having a diameter of 30,000 light years, a body then falling from an infinite distance to the center of such a system would acquire a velocity of 25 miles per second, and if projected from the center of such a system at a velocity greater than 25 miles per second, such a body would pass through and

fly off into space. 1830 Groombridge, that has a velocity of 200 miles per second, would therefore fly away into space and regard the attraction of such a universe as the mere brush of a fly's wing. Whence then did 1830 Groombridge come?

The most recent determinations of the apex are those of Newcomb, Kapteyn and Campbell, varying in R. A. from 274° to 277°, and in D. from 20° to 25°. This gives us a general direction variously placed in Lyra between Cygnus and Hercules, and the last result is about midway between *Alpha Lyræ* and *Beta Lyræ*. The rate of motion is put at 1,070,000 miles a day, or 391,000,000 miles per annum, and with this stupendous velocity the Sun approaches 61 *Cygni*, which is the nearest visible star to us. Can it be that the nearness of this star is in part a consequence of the solar advance during the ages of the illimitable past, and when our anthropoid ancestors were enjoying their arboreal habits how much further away was 61 *Cygni*? Our system is not in an ocean of space, but only crossing some inlet in some mighty orbit with a curve so vast as to defy computation. Will we reach some turn in the millions of years yet to come? Will this mighty astrodome wherein we rush reach some far-distant apse, some infinitely distant apo-astron, and then will we swing round in our course? Great Hercules is yearly becoming larger and brawnier,—his club, and especially his bow, growing every year more formidable. This solar flotilla sails away through this vast gulf or inlet towards Hercules in an orbit so immense that the part which has been observed from the date of the earliest accurate observations does not differ sensibly from a straight line. Shall we double the wondrous cape of our great ellipse, and as we return will the Dove begin to expand and plume her heavenly wings while champion Hercules will dwindle behind us? Mädler has placed the focus of this immense star sweep in Alcyone of the Pleiades, and there she lies steeped in that breathless quietness and uttermost sleep where the earliest discoverer saw her, lying sunk in space at a depth too great to fathom, and out-shining our own Sun a thousandfold. Archibald Lampman's magnificent description is hardly overdrawn,—

"Alcyone the great and burning star,
Immeasurably old, immeasurably far,
Surging forth its silver flame
Throughout Eternity."

And here the poet astronomer places the center of this magnificent totality of revolving orbs and firmaments. Thus the capital of creation may be this single visible star that is poised in perfect balance while the whole material universe in flaming squadrons courses round about. Is it then the throne of the great Divine architect, creator and preserver? Speculations of this kind are interesting, they are attractive, they are uplifting. Nay, they present a field for eager enquirers to investigate and they develop the devout nature of man, for indeed cold, calculating logic is not the whole of man's mental arsenal. Creation is steeped in mysteries, but still science must be satisfied. With uplifted head and enquiring eye she demands evidence of all that is presented for acceptance, and as to this magnificent generalization of a central Sun, it must be admitted that the evidence is far from complete. Sir John Herschel pronounced the theory of a common movement around the Pleiad lying 26° out of the plane of the galactic circle as utterly improbable. Out of this plane he says it is almost inconceivable that any general circulation can take place. He suggests a close observation of the right ascensions and declinations of stars in the Milky Way, judiciously selected, and including all magnitudes, to discover a rotation of the galaxy in its plane. He adds that 30 or 40 years of observation, perseveringly directed to the object in view, could not fail to settle the question. If we cannot hold the theory of a great Pleiad center orbit, yet we have the bed-rock of evidence for the theory of the rectilinear movement of the Sun through our cluster. We are then on our way to 61 *Cygni*. At the rate of 391,000,000 miles a year, we will arrive at that station in 121,000 years, roughly. We are crossing the coal-sack region, that black chasm of emptiness that surrounds our solar system continent like an ocean dark as Erebus. The earth inhabitants will be seeing a new heavens a few thousand years hence. The

firmament will sparkle with new glories, and the constellations opposite Vega will have paled and dwindled away. Twelve thousand years hence Vega will be our pole star, and we will be driving head onwards towards the North Pole. The life of our solar system is thus spent in a glorious panorama of a changing firmament, and while individually our lives are spent as a tale that is told and we see only a small portion of the Universe, yet through the distant ages yet to be Apollo will drive his sun chariot through new celestial scenery where stars now invisible "wander with golden feet."

Many insects live a day, and to them the life of man is as infinite. There may be intelligences in creation compared to whom we are perishable ephemerides, and to them may be granted the glorious gift of gazing upon the ghostly infinitude, the changing, shifting scene of our great journey through the space of our solar nebula. Near Vega, the great Harp Star, is our apex. Its name is Arabic. It means "the falling eagle." Its sapphire hue dazzles us. It is the arc-light of the sky hung near the zenith. And will our remote posterity get a nearer view of the celebrated quadruple star? And will the great Ring nebula in Lyra unfold its dim nebulous haze and let its secret be read by the astronomers of the far-distant age? This Lyra is the harp of Orpheus which sounded such harmony when swept by the Master Musician; he sang,—

> "Such notes as warbled to the string,
> Drew iron tears down Pluto's cheek
> And made him grant what Love did seek."

And will the great Hercules cluster, that little patch of sky which is a glorious company of glowing suns, draw near? And will our earth in the far-away future become neighbor to those countless sparks that are there packed together like the boss of a blazing shield? Speculation runs almost rife with us, and we may give the rein to our conjecture, and that is legitimate enough, so long as we do not discard or trifle with scientific truth.

MEETINGS OF THE SOCIETY

AT TORONTO

April 7.—The following were elected members of the Society :

R. A. Gray, B.A., Toronto,

Rev. William Henderson, Plattsville, N. S.

The librarian called attention to the fact that certain books are missing from the Library, and asked any member who had any of them to return them.

Mr. A. R. Hassard gave a list of occultations for the following fortnight and asked why such a list was omitted from the *Handbook* for the present year. Dr. Chant explained that the subject was duly considered at the time of the preparation of the material for the *Handbook*, but that it was deemed inadvisable to publish one list, applicable to observations in one place only, and therefore not useful to observers in general, while the labor of preparing material for use in different places was too great to be undertaken for such a publication.

Mr. Hassard reported having observed the conjunction of Venus and Saturn with the Moon on the 4th instant, and dwelt especially upon the beauty of the detail visible that evening on the dark portion of the Moon, in the region of the mountain Plato.

The lecture was by Prof. A. P. Coleman, upon the subject of "Ancient Ice Ages," and was elaborately illustrated with lantern slides. Notice of the lecture appears in this number of the JOURNAL. It was followed by an interesting discussion, in which Messrs. Inrig, Ridout, Paterson, Muir, Elvins and Musson took part.

April 21.—The following was elected a member of the Society :

L'Abbé van den Bossche, Director of the Convent of St. Vincent, Selzate, Belgium.

Mr. A. R. Hassard reported that he witnessed on the 9th instant the occultation of five stars in the constellation of Cancer. Mr. R. S. Muir referred to the present brilliance of Venus, and the power of the planet to cast a shadow.

Mr. Muir inquired whether any explanation is given as to why Bode's law is not exact, while it is accepted as a law. This led to some discussion in which Messrs. Musson, Maybee and Collins took part.

Mr. Hassard referred to the difference of opinion which exists regarding the magnitudes of the stars, and asked for some explanation. The reply was given that star magnitudes are now made by photometric measurements, and that there is no uncertainty as to magnitudes computed by that method.

Mr. Collins drew the attention of the Society to the fact that in the March number of the *Astrophysical Journal* there are articles by Dr. King and Mr. Plaskett and a short note by Mr. Harper, a very creditable showing for Canadian astronomers.

The paper was by Mr. W. J. Wintemberg, on "Some Myths and Fancies of the Milky Way." Mr. Wintemberg gave the result of much research into the ideas of the ancients and of primitive people generally. Mention was made of the fact that the ancients early suspected the true character of the Galaxy, which conjecture was confirmed in Galileo's time. The views of such early writers as Aristotle, Democritus, Parmenides, Theophrastus, and others were also given. The poetic side of the subject was not neglected, the allusions from ancient and modern poets showing that this starry zone has been a favorite theme of the poet. It was apparent from some of the myths and fancies presented, that many of them were much inferior to the higher conceptions of the more cultured Greeks; although even some of these are in many respects almost as crude and puerile as those of the American Indians and the Bushman of South Africa. Various names applied to the Milky Way were

also given, and the subject throughout was treated in a most interesting manner. The paper was followed by an interesting discussion in which Messrs. Maybee, Miller, Musson and Collins took part.

May 5.—Prof. W. W. Campbell, Director of the Lick Observatory, presented to the Society four lantern slides made from photographs of the Corona taken on January 3 last by the observatory's expedition to Flint Island. Hearty thanks were ordered to be sent to Professor Campbell.

Mr. J. E. Maybee mentioned that Mr. Elvins is to-day celebrating his 84th birthday, and moved that the congratulations of the Society be extended to Mr. Elvins, in recognition of his long services to the Society and to astronomy in Toronto generally. The motion was seconded by Mr. Paterson, who paid high tribute to Mr. Elvins' attainments as an astronomer, and was carried with applause.

Mr. John A. Paterson referred to an interesting spectacle on the evening of the 3rd of May, when the Moon, Venus, Mars and Aldebaran formed a very striking four-sided configuration, a curious and beautiful sight on the clear evening sky.

Mr. A. F. Miller reported that the phase of Venus at present is that of a full crescent. He also referred to a peculiar shading visible on the inner portion of the crescent, and some discussion took place as to its probable cause.

The subject of the possibility of photographing the rainbow was also discussed.

The paper was by Mr. J. Edward Maybee, M.E., upon the subject of "Star Magnitudes." Mr. Maybee showed the lack of uniformity which has existed respecting the measurements of the light of the stars, and the methods which are now employed. Dr. Chant explained the method employed in using the polarization photometer, and questions respecting the intensity of light were discussed. Mr. Miller gave his experiences in arriving at star magnitudes, by comparing one object with another, by ex-

amining them with the telescope slightly out of focus; and referred to his observations of *Mira*, which he has followed closely for many years. The address was most interesting and will, it is hoped, appear in the JOURNAL.

May 19.—On motion Dr. W. F. King, Mr. Joseph Pope, and Mr. R. Stewart Muir were appointed delegates to represent the Society at the coming meeting of the Royal Society of Canada at Ottawa.

Mr. A. F. Miller reported that he had again observed the darkening of the terminator of Venus to which he referred at the last meeting, though it was not so deep a shadow as he had previously seen. He stated that he considered it probable that the shadow was at times exaggerated by the tremor of the atmosphere.

The proposal to institute a Question Box was received with much favor, and it was decided to have at the next meeting answers to several questions which had been handed in.

The paper for the evening was one contributed by Rev. J. T. W. Claridge, M.A., F.R.A.S., Burton-on-Trent, England, and was read by the Recorder. It dealt in a very interesting manner with the life of the great astronomer Sir William Herschel. His great ability as a musician, an optician and an astronomer was referred to, and a full account of the assistance rendered by his sister Caroline was given. At the close of the paper several portraits of the Herschel family were shown on the screen.

June 2.—The following was elected a member of the Society:

R. L. Hutchinson, Director of the Meteorological Observatory, St. John, N. B.

Mr. R. S. Muir gave a most interesting report of the proceedings of the Royal Society of Canada, held at Ottawa last week, which he attended as a representative of the Society.

The President expressed the thanks of the Society to Mr. Muir for his report, and predicted that there will next year be a large number of applicants for appointment as delegates to attend this meeting.

Referring to one of the papers given before the Royal Society of Canada at its meeting, respecting a method of revision of the calendar now being promulgated in England, for which Sir Sandford Fleming stands sponsor in Canada, Mr. Tyson reminded the members of a paper given by Dr. A. D. Watson some years ago before this Society upon the same subject.

The paper was one contributed by W. H. S. Monck, M.A., F.R.A.S., Dublin, on "The Sun's Motion in Space." The paper was read by Mr. Paterson, who elucidated various points in his usual happy manner. The paper was a valuable contribution, and will appear in the JOURNAL. The discussion which followed was interesting, and was taken part in by Messrs. Elvins, Tyson, Musson, Chant and Miller.

Various questions which had been asked at the last meeting were then taken up. One, respecting the computation of comets' orbits was answered in part by Dr. Chant, who referred to the fact that he had received a communication from Mr. Denning of Bristol respecting the publication of a table of periodical comets in the *Handbook*, also a letter from the Astronomer Royal at the Cape of Good Hope, asking for a copy of Mr. Plaskett's article on *Mira Ceti*. E. A. D.

AT OTTAWA.

April 16.—Dr. Otto Klotz read his paper on "Latitude and Longitude." The first to make use of latitude and longitude were the Phœnicians about 3000 years ago, the world as known to the ancients comprising the countries around the Mediterranean sea. The ancient world west and east was much longer than north and south, hence *longitude* and *latitude*. Hipparchus introduced refinements into the methods, but navigation did not make much real progress until the introduction of the mariner's compass in the fourteenth century. Dr. Klotz explained the determination of latitude by the use of the gnomon and showed its similarity in principle to the modern transit. For longitude, Hipparchus suggested the use of lunar eclipses, which take place at a stated time, and later the phenomena of the satellites

of Jupiter were suggested for the same purpose. The gradual development in the methods of accurately determining latitude and longitude was interestingly traced. The substitution of the quadrant and the sextant for the gnomon enabled the latitude to be accurately obtained, but the longitude was a more difficult matter. The importance of the accurate determination of these coördinates in navigation was early recognized and a large reward was offered by the British Government for a chronometer that would keep accurate time. For latitude the equator is the fundamental circle, while longitude has an arbitrary initial meridian. Dr. Klotz recounted the changes which had taken place in the position of the principal meridian until the final adoption in 1884 of the Meridian of Greenwich as the universal meridian of 0°. The instruments used and the methods employed in obtaining accurate determinations of latitude and longitude were described and illustrated by lantern slides. Dr. Klotz then explained the use of these determinations in making maps and for other purposes. He showed how the accuracy of the values depended on the direction of the plumb line and how this could be deviated by local conditions, such as mountain masses, so as to introduce errors of several hundred feet in the latitude and longitude. This was illustrated by a map of the international boundary between Canada and the States of Washington, Idaho and Montana, showing the zig-zag nature of the line determined astronomically, and the connection between these deviations and adjacent mountain formations.

The lecture was listened to with close interest by the large number of members present and a short discussion ensued.

For the Question Box two questions had been sent in.

1. Why is there no thunder and lightning during the winter?

2. Why do comets recur at such irregular intervals and of such different intensities and when does Halley's comet appear?

The first question was answered by Dr. Klotz; the second by Mr. R. M. Motherwell. After announcing the paper for the

next meeting, Dr. Klotz invited those present to have a look through the telescope.

April 30.—Mr. R. M. Stewart read his paper on the "Errors of Transit Observations." The author first gave a synopsis of the results obtained and the conclusions reached in a former paper under the same title.* It was shown that the discordances in Transit Observations were not materially reduced by the substitution of the transit micrometer for the key method and hence they are not due to personal equation. They are larger than should be expected from the probable errors and hence systematic with respect to any one time set. Mr. Stewart concluded that they were probably due to azimuth error caused by accidental errors in the observations of polar stars. He then described a series of observations taken to show that the discordances are due to azimuth errors. A comparatively large number of polars were observed in a set and by selecting these in pairs for combination with the south stars, discordances of the same order of magnitude were obtained. It was also shown that large discordances between time sets on the same night are invariably reduced by the adoption of an azimuth depending on a large number of observations of north stars.

Mr. Stewart then discussed theoretically the proper arrangement and distribution of stars in a time set, and computed weights corresponding to the relative values of different arrangements. These computations showed very clearly the decided advantage gained by observing both north and south stars as close to the zenith as possible. This, however, can be done, even approximately, only with a transit instrument of the broken type: with the ordinary type within 20° of the zenith is the practical limit. The relative number of north and south stars to be observed depends on their zenith distances, and providing the numbers be selected properly, accuracy is increased by diminishing zenith distances of both north and south stars. This is impossible in the case of north stars because the number required near the zenith is excessive, and a compromise must be made.

* This JOURNAL, Vol. I., p. 228, 1907.

Mr. Stewart then gave results showing the increase in accuracy obtained by the reversal of the instrument during the observation of each star, and concluded by giving a summary of the conclusions reached from his investigations of the best practical methods of increasing the accuracy of a time determination.

1. The accuracy is increased about two-thirds by a reversal of the instrument during the observation of each star.

2. Errors due to defective azimuth may be lessened by observing all south stars as near the zenith as possible. This will in general mean an average zenith distance of 20°.

3. Azimuth errors may also be diminished by increasing the number of north stars in a set. If they have a mean zenith distance of about 30°, one north and two south stars should be observed.

Dr. Klotz in discussing the paper spoke in very complimentary terms of the able manner in which the work had been conducted, of the clearness with which it had been presented and of the importance of the results. Mr. Plaskett also expressed his admiration of the work, his appreciation of the value of the results and expressed the hope that it would soon be published in a suitable medium where it would undoubtedly bring credit to the author and the Dominion Observatory.

May 14.—Mr. Joseph Pope read his paper on "The Planet Mars." He began by describing in a graphic way the occasional appearances of a bright red star in the southern sky. The planet Mars had always excited much interest and a short account of the historical side of the subject was given.

Mr. Pope then explained, illustrated by a diagram, the cause of the varying brightness of the planet. He pointed out that the most favorable positions for observation occur in the month of August and clearly explained the reason. The apparent size of the planet as viewed by the naked eye was given, as also the size as observed in large telescopes, and the application of this to the possibility of observing the markings, the well-known canals of Mars. These were first seen by Schiaparelli in

the clear skies of Italy, who has been followed by other observers, chiefly Percival Lowell in the dry and transparent air of the elevated plateau of Arizona.

Mr. Pope showed lantern slides of the chief markings on Mars, the polar caps and the canals, and interestingly discussed the theories brought forward by Lowell to account for the changes in these markings. The main points in favor of, as well as against, Lowell's theory were clearly stated, and while doubting the objective reality of some of the markings observed on Mars by Lowell and his observers, Mr. Pope's conclusion was that the evidence was on the whole convincing that some condition on Mars similar to that cited by Lowell accounted well for the observed features. The question of the possibility of life on Mars was also well discussed, and although no definite conclusion was, or can ever likely be, reached, the possibility and even probability of some life existing on the planet was brought forward.

The lecture was listened to with close attention by a very large gathering of members and an interesting discussion participated in by several members.

For the Question Box the cause of the apparent backward and forward motions of the planets among the stars was fully answered and explained by Dr. Klotz.

May 28.—The President called on Mr. Plaskett for his paper on the "Design of Spectrographs."

The paper began with some remarks on the necessity of limiting in so wide a subject the treatment to one particular application of spectroscopy. The designing of spectrographs for radial velocity determinations is a judicious combination of theory and practice. The necessity for the most careful attention to all details was pointed out, this being due to the exceedingly small displacements to be measured, one kilometre per second corresponding to $\frac{1}{50000}$ inch with a single-prism spectrograph.

A short summary of the principles of the spectroscope was then given, followed by the development of the principal formulæ required in spectrograph design. These embraced formulæ for

finding the prism angle for any given deviation and index of refraction, the length of side and base, the total and partial dispersion, the resolving power, and finally the purity. The application of the results obtained in a previous paper on the percentage of star light transmitted by slits of different widths to the present problem was given, and this showed that an increase in slit width meant almost a proportional increase in the quantity of light transmitted and a corresponding decrease in exposure time. It was shown that an increase of slit width, however, diminished the purity and the accuracy of the resulting measures, and the only practical way of overcoming this was to increase the size of the prism. Calculations were then performed which showed that an increase in size from 35 mm., the aperture of the present instrument used at the Dominion Observatory, to 51 mm., the aperture of a proposed new single prism instrument, would allow the slit to be made 50 per cent. wider with the same purity of resulting spectrum. Further calculations on the amount absorbed by the two prisms showed that after allowing for the increased absorption, a beam of star light producing a spectrum of equal purity and equally accurately measurable in the two cases will have about 1⅓ the intensity with the large prism, and consequently will require only ¾ the exposure. The application of an investigation on the effect of increasing the width of slit on the accuracy of the resulting spectra, which had been recently carried out by Mr. Plaskett, also served to confirm the above results, and the conclusion was reached that the use of a larger prism would mean a considerable advance in efficiency.

Mr. Plaskett then discussed the mechanical structure of the instrument, illustrating his remarks by lantern slides of the present instrument and of drawings of the new one. The features of the design of each were pointed out and the advantage of the new type, by which it was hoped entirely to remove flexure and minimize temperature disturbances, were explained.

Since the last minutes Mr. J. H. Labbe of the Dominion Observatory has been elected to membership. J. S. P.

AT PETERBOROUGH.

April 30.—At a previous meeting the discussion of some "Questions" had proved very helpful, and a list had been prepared for this meeting. They had been published in a daily newspaper and aroused much interest. They included:

1. Give explanations of:—variation of latitude, Kepler's Laws, equatorial telescope, refraction, Solar system.

2. What are apparent solar time, mean solar time, equation of time?

3. How do astronomers determine the times at which certain stars will cross a given meridian?

4. Were the recent solar disturbances, as evidenced by sunspots, accompanied by any remarkable effects?

Explanations of the above were given by Dr. Marsh and Mr. H. B. Collier.

Mr. Frank P. Jennings, M. Inst. C.E., a member of the Labrador Eclipse Expedition in 1905, read a paper prepared by his father Mr. Samuel Jennings, of Derby, England, on "Solar Eclipses and Ancient History." The paper explained how interesting and valuable for purposes of chronology are references to ancient eclipses. The identification of these ancient eclipses, however, has been considered by some distinguished astronomers quite impossible, but during recent years new light has been thrown on the subject by the researches of Mr. P. H. Cowell, F.R.S., of the Royal Observatory, Greenwich. The new results penetrate into the domain of history and suggest reasonable solutions of some difficulties which have perplexed students of the classics and of biblical literature.

More than two centuries ago, in 1693, Halley showed that the month was slowly changing in length, and the amount of this change was first correctly measured by Prof. Simon Newcomb, who discussed in 1878 the times of nineteen eclipses recorded by Claudius Ptolemy as having taken place between B.C. 721 and A.D. 136. As these did not accord with his calculations he rejected them as untrustworthy. Mr. Cowell finds that this want

of accord may be explained by the hypothesis that the ratio of the length of the day to that of the year is slowly changing. Under this supposition various ancient eclipses become self-consistent, the most ancient of all being one observed in Babylon, B.C. 1063.

The paper gives many illustrations of the way in which references in Xenophon, Herodotus, the Bible and inscriptions on the monuments are brought into harmony with modern astronomical calculations. It is hoped to publish the paper in full in a later number of the JOURNAL.

On motion of Mr. H. O. Fisk and Mr. D. E. Easson a hearty vote of thanks was given Mr. F. P. Jennings. E. F.

NOTES FROM THE DOMINION OBSERVATORY

Astrophysics.—Owing to loss of time and to uncertainties in the temperature conditions in changing from the single to the three-prism form of the spectrograph or *vice versa*, it has for a considerable time been felt desirable that a separate single-prism instrument should be obtained. With the approval of Dr. King the optical parts were ordered from the J. A. Brashear Co. and have recently been received. The design has been completed and the mechanical construction has been begun in the workshop. The instrument will embody many new features, and will, it is believed, be a distinct improvement over previous spectrographs.

The star B. D. $-1°\cdot1004$, a spectroscopic binary announced by Frost in 1906, was under observation here during the past winter. Its velocity curve bears a striking resemblance to that of ι *Orionis* recently published, and its period is nearly the same. So far as the observations go they indicate an even higher eccentricity than ι *Orionis* (0·75) and a longitude of the apse not far from 90°. Observations will be actively continued as soon as the star can be conveniently observed in the fall.

The spectro-comparator has been used by the writer in measuring a number of spectra of β *Geminorum* made with the three-prism spectrograph with satisfactory results. One spectrum, No. 1373, has been repeatedly measured with different fundamental spectra, with two different ocular prisms and with different magnifying powers. The results obtained show that the probable error of measurement is quite small, about 0·1 km. Hence much more accurate results can be obtained in solar-type spectra with this instrument in the ordinary way and in considerably less time. The range of spectrum measured extends from λ 4200 to λ 4660, but it could if desired be extended to λ 4900 as the Zeiss "Chromat" Camera Lens gives excellent definition over the whole length of plate λ 4100 to λ 4900.

The first fundamental spectra were made on Lantern and Process plates which had the drawback of being only slightly

sensitive to the red side of λ 4600, and which could not be used beyond this region. No brand of ordinary emulsion tried gave sufficient detail and contrast for the purpose. A new lot of Seed Process plates was recently received, which to my surprise gave almost the same range of sensitiveness as the ordinary silver bromide emulsion, extending to about λ 5000 instead of λ 4600, and they consequently answered the required purpose admirably. Evidently the makers have, within the last few months, changed their Process emulsion, in this particular case greatly for the better.

Work on the cœlostat house is making satisfactory progress and it will soon be ready for the installation of the instruments and for beginning the actual work of solar research.

Mr. T. H. Parker, B.A., has been appointed as assistant in the astrophysical division, and is engaged in measuring star spectra.

Mr. L. Gilchrist, B.A., Lecturer in Physics, University of Toronto, will, during the summer months, undertake some investigations at the Observatory with the grating spectroscope.

J. S. P.

The Seismograph—Bosch Photographic—Magnification 120.—Microseisms have been freely recorded during April and the beginning of May, more so than during March. On the following days the maximum amplitude reached was at least 1 mm.: April 3, 4, 10, 11, 12, 13, 14, 16, 17, 18, 20, 21, 28, 29; May 3, 4, 5, 10. From May 17 to the end of the month there was apparent quiesence, but on examinations of the seismogram with a magnifier, on some days very minute and very rapid oscillations, especially by the E–W pendulum, are shown. These oscillations for that pendulum have a period of about $2^s{\cdot}7$ and for the other pendulum about $4^s{\cdot}3$. Probably in the next number of the JOURNAL the writer will give in a separate article a synopsis of the relationship which he has apparently found to exist between the occurrence of the usual type of microseisms, with periods of 5^s to 6^s, and the atmospheric isobars and gradients dependent thereon, more particularly with reference to the *position* of the

area of low barometer and to a less degree of high barometer.

Several macroseisms were recorded of which the following are brief notes :—

April 19. A slight shock

	N–S Component	E–W Component
	h m s	h m s
1st P. T. began	8 21 04 (?) G.M.T.	8 21 02
2nd " "	8 24 16	8 24 14
Max. amplitude	2 mm.	6 mm.
Duration about	34 m.	39 m.

April 23. A slight shock. Microseisms are generally better shown by the pendulum mounted E–W, *i.e.*, giving the N–S component, than by the one at right angles to it, while for macroseisms the pendulum mounted N–S generally gives the more decided record.

In this small quake there was much irregularity of the zero line, which is not the case in the record of a strong tectonic quake until near its end.

	N–S Component	E–W Component
	h m s	h m s
1st P.T. began	0 07 40 (?) G.M.T.	0 07 36 (?)
Max. amplitude	1 mm.	2 mm.
Duration	1 43	2 09
Long waves of 30s period set in	1 00 00 about	0 46 00 about

May 13. A small quake recorded in afternoon.

	N–S Component	E–W Component
	h m s	h m s
1st P.T. began	20 43 47 G.M.T.	20 43 46
2nd " "	20 45 16	20 45 42
P.P. began	20 48 45 (?)	. . . . .
Duration	1 02	. . . . .
Max. amplitude	3 mm.	2 mm.

May 15. A severe earthquake.

	N–S Component	E–W Component
	h m s	h m s
1st P.T. began	8 39 25 G.M.T.	8 39 22
2nd " "	8 45 32	8 45 32
P.P. began	8 52 20 about	8 52 00 about
Duration	1 30	2 30
Max. amplitude	23 mm. at $8^h\ 53^m\ 40^s$	34 mm. at $8^h\ 53^m\ 30^s$

From the above data the distance of the epicentre is found to be about 4,600 km., say 2,900 miles. Two seismic regions correspond to this distance,—the area in Alaska between Mt St. Elias and Prince William Sound, and the southern part of Columbia north of Quito in South America. As the Washington record shows the first preliminary tremors to have arrived there about half a minute later than they did in Ottawa, it seems probable therefore that the earthquake occurred in or on the shores of Alaska.

O. K.

ASTRONOMICAL NOTES

At a recent meeting of the British Astronomical Association E. Walter Maunder, regarding the origin of the divisions of time, said "he might refer to a suggestion made to him by his wife whilst he was writing the book on the *Astronomy of the Bible*, which he had just brought out. If there are any inhabitants upon Venus they are in rather a bad way for all divisions of time, if the theory be true that Venus always turns the same face towards the Sun. They would, in that case, have no 'day.' Next, as they had no Moon, they would have no 'month'; and, thirdly, as the axis of Venus was supposed to be perpendicular to the orbit, which was practically a circular one, there would be no 'year,' and, therefore, they had no means of dividing the time at all. He did not know how Mr. Lowell would find that state of things fitted in with the habitability of Venus, but if there were inhabitants of Venus, and they managed to measure time, they must be accomplished mathematicians, and this should help when they came to cover Venus with canals like those on Mars."—*Journal British Astronomical Association*, May 21, 1908.

The Determination of Longitude at Sea.—The Paris Academy of Sciences has appointed a committee, consisting of MM. Becquerel, Bouquet de la Grye and Poincaré, to consider a suggestion made by M. Bouquet de la Grye. The proposal is to send every night a Hertzian signal from the Eiffel Tower giving midnight for the meridian of Paris. It is thought that if a station were established on the Peak of Teneriffe, signals might be detected all round the earth.—*Ibid.*

An annular eclipse of the Sun, June 28, will be visible in Canada (except in the extreme north-west portion) as a partial eclipse. The path of central eclipse crosses Mexico, Florida, and ends in Western Africa. At Montreal it begins $9^h\ 56{\cdot}1^m$ and ends $12^h\ 49{\cdot}0^m$. At Toronto it begins $9^h\ 43{\cdot}9^m$ and ends $12^h\ 38{\cdot}7^m$, 75th Meridian Time.

J. R. C.

SUMMARY REPORT OF THE WEATHER IN CANADA

APRIL, 1908

TEMPERATURE.—The mean temperature for April was above average from the Thunder Bay District of Ontario to the Rocky Mountains, whilst elsewhere in Canada it was subnormal. In the southern districts of the Western Provinces, positive departures of 3° were general, while over a large portion of Ontario, Quebec, and the Maritime Provinces, the negative difference from average was more than 3°, and in the Ottawa Valley was from 5° to 7°.

For the highest and lowest temperatures at various stations see the accompanying table.

PRECIPITATION.—The amount of precipitation recorded during April was much less than average from British Columbia to Eastern Manitoba, except very locally in Alberta where the fall was slightly in excess of the normal; while in Ontario, Quebec, and the Maritime Provinces a supernormal amount was recorded, except in Central and Eastern Counties of Ontario, where the amount was less than usual. The precipitation was partly snow in most districts.

MAY, 1908

TEMPERATURE.—The mean temperature was supernormal throughout Canada except in the southern and western portions of British Columbia, where the average was not reached. Departures were, however, nowhere excessive, amounting to but a few degrees.

For the highest and the lowest temperatures at various stations see the accompanying table.

PRECIPITATION.—The precipitation during May was in excess of the normal over the greater portion of Canada, but a fairly pronounced deficiency occurred over a large part of Saskatchewan and small deficiencies more locally in British Columbia and in parts of Ontario, especially near the shores of Lakes Erie and Huron. Over most of Ontario and in Western Quebec the rainfall was nearly double the average amount, while further east in the Lower St. Lawrence Valley and in the Maritime Provinces the average was exceeded by smaller amounts.

Temperatures for May and June

Station	May		June	
	Highest	Lowest	Highest	Lowest
Yukon				
Dawson	59	−13	78	26
British Columbia				
Agassiz			70	35
Atlin	50	10	68	24
Barkerville	74	10	64	22
Glacier	50	9		
Golden	65	8		
Kamloops	76	22	78	38
Ladner			67	35
New Westminster	78	30	68	36
Port Simpson			66	32
Steveson	60	31		
Vancouver	77	30	66	38
Victoria			66	40
Western Provinces				
Banff	59	−13		
Battleford	82	−10	84	22
Brandon	82	− 1		
Calgary	74	3	82	25
Carman			78	48
Edmonton	70	− 5	84	29
Estevan	82	− 8		
Hillview	80	16		
Indian Head	76	−10		
Medicine Hat	82	− 3	90	30
Minnedosa	79	4	80	16
Morden	81	2		
Prince Albert	78	− 4	80	19
Regina	79	−16	83	20
St. Albans	85	3		
St. Peters	66	−15		
Swift Current	84	− 2	80	25
Winnipeg	74	2	84	22
Ontario				
Agincourt	73	16	82	33
Alton	75	2		
Bancroft	66	3	84	26
Beatrice	67	2	82	24
Brantford	73	18	87	26
Bruce Mines	63	− 4	73	27
Clinton	71	17	84	30
Cockburn Island	65	0	75	27
East Toronto			84	32
Gravenhurst	68	− 1		
Haliburton	69	− 7		
Huntsville	66	− 4	83	26
Kingston	65	13	76	33
Kinmount	66	4		
Lake Talon	68	1	84	26
Lucknow	73	8	84	30
Madoc	69	9		
Meaford	72	13	85	27
Midland	72	15	90	35
North Gower	72	7		
Otonabee	69	13	83	34
Ottawa	64	8	85	33
Owen Sound	74	14	90	26
Paris	74	19	88	27
Parry Sound	72	0	86	29
Peterboro'	69	10	85	28
Point Clark	67	16		
Port Arthur	75	− 2	83	28
Port Burwell	71	15	80	28
Port Dover	68	19	83	27
Port Stanley	64	19	80	30
Rockliffe	62	3	84	25
Ronville	60	− 5	83	23
Sarnia	78	22	88	34
Southampton	72	12	82	26
Stony Creek	73	21	88	28
Stratford	68	1		
Toronto	75	17	84	29
Uxbridge	70	10	83	25
Wallaceburg	76	21	86	32
Welland	75	20	90	32
White River	62	−20	82	12
Windsor			83	33
Quebec				
Brome	75	4	80	30
Father Point	47	6	70	30
Montreal	66	7	82	36
Quebec	58	1	79	32
Sherbrooke	70	5	81	32
Maritime Provinces				
Charlottetown	60	16	76	29
Chatham	76	11	84	29
Fredericton	73	9	79	29
Halifax	66	17	78	31
Hamilton, P.E.I.	58	13		
Moncton	72	11	77	29
Port Hastings	71	12	65	27
St. John	64	12	74	34
St. Stephen	77	10	80	28
Summerside	61	14	72	28
Sussex	69	9	79	30
Sydney	56	16	75	28
Yarmouth	63	20	68	32